

## Example

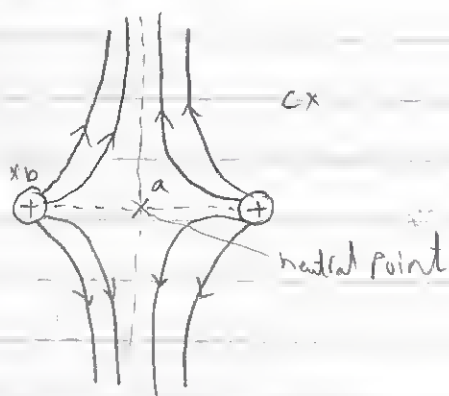
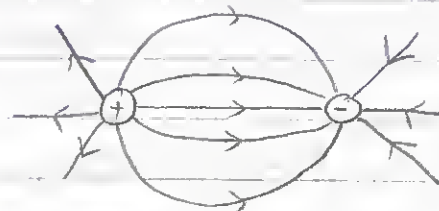
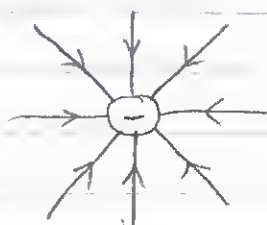
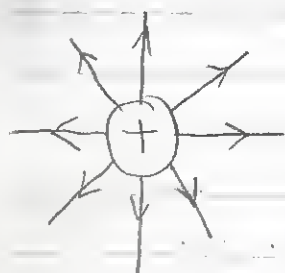
$$dE = k \frac{\lambda dx}{x^2}$$

$$E = k \lambda \int_d^{L+d} x^{-2} dx \quad , \quad E = k \lambda \left[ -\frac{1}{x} \right]_d^{L+d}$$

$$= -k \lambda \left( \frac{1}{L+d} - \frac{1}{d} \right) = k \frac{\lambda L}{d(L+d)} \quad , \quad E = k \frac{Q}{d(L+d)}$$



## Electric field lines



uniform field



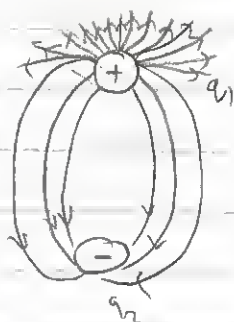
$$E_a = E_b$$

$$E_b > E_c > E_a$$

## properties

- 1- Electric field lines do not form closed loops i.e. it can have a beginning or an end or both
- 2- Using electric field lines we can determine regions of strong/weak field
- 3- No intersection between 2 field lines
- 4- magnitude of charge is directly proportional to electric field lines

5)



Find ratio of  $q_1$  to  $q_2$

$$\frac{q_1}{q_2} = \frac{20}{6}$$

## Gauss's law

Electric flux ( $\Phi$ ): It's the no. of electric field lines crossing normally through surface area ( $A$ )

### 1) Flux of uniform field

i)  $\vec{E} \perp \vec{A}$

$$\Phi = EA$$

unit:  $\frac{N}{C} m^2$



field into paper

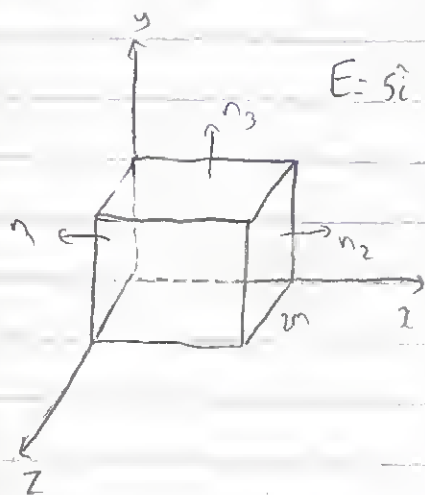
ii)  $\vec{E}$  makes angle  $\theta$  with  $\vec{A}$

$$\Phi = EA \cos \theta$$

$$\Phi = \vec{E} \cdot \vec{A}$$



6)



$$\vec{E} = 5\hat{i} \text{ N/C}$$

$$\Phi_1 = \vec{E} \cdot \vec{A}_1$$

$$= 5\hat{i} \cdot (4\hat{i} - 4\hat{j}) = -20 \frac{N}{C} m^2$$

$$\Phi_2 = \vec{E} \cdot \vec{A}_2$$

$$= 5\hat{i} \cdot 4\hat{i} = 20 \frac{N}{C} m^2$$

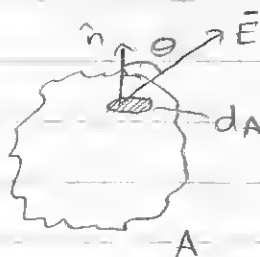
$$\Phi_3 = \vec{E} \cdot \vec{A}_3$$

$$= 5\hat{i} \cdot 4\hat{j} = 0$$

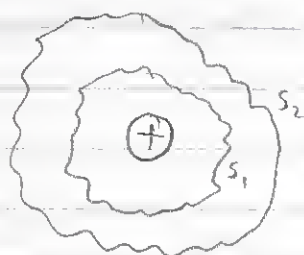
## b) Flux of non uniform field

$$d\phi = \vec{E} \cdot d\vec{A}$$

$$\phi = \int \vec{E} \cdot d\vec{A}$$



## Net flux ( $\phi_{\text{net}}$ )



$$\phi_1 = \phi_2$$

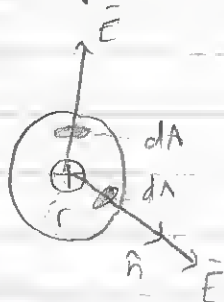
$$\phi_{\text{net}} = \oint \vec{E} \cdot d\vec{A}$$

closed surface

Net Flux does not depend on

1. Geometry of closed surface
2. Size of closed surface
3. position of charge in closed surface

## Net flux of a point charge

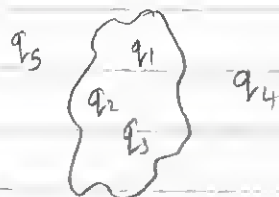


charge in centre  $\Rightarrow \theta = 0$

$$\begin{aligned} \phi_{\text{net}} &= \oint E \cdot dA \\ &= E \oint dA = EA \end{aligned}$$

$$= \left( \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r^2} \right) 4\pi r^2 = \frac{q}{\epsilon_0}$$

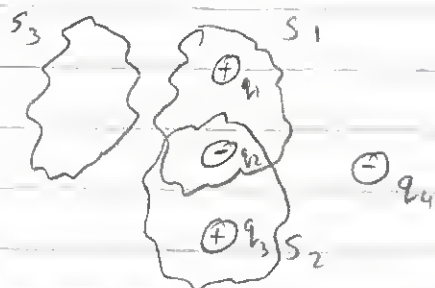
for  $N$ -point charges



$$\phi_{\text{net}} = \frac{q_1 + q_2 + q_3}{\epsilon_0}$$

\*  $q$  is used with its charge

Ex) Find  $\phi_1, \phi_2, \phi_3$



$$\phi_1 = \frac{q_1 - q_2}{\epsilon_0}$$

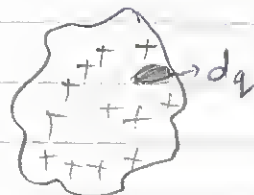
$$\phi_2 = \frac{q_3 - q_2}{\epsilon_0}$$

$$\phi_3 = 0$$

Net flux of continuous charge

$$\int d\phi = \int \frac{dq}{\epsilon_0}, \quad \phi = \frac{1}{\epsilon_0} \int dq$$

$$\phi = \frac{Q}{\epsilon_0} = \frac{q_{\text{inside}}}{\epsilon_0} = \frac{\sum q}{\epsilon_0}$$



$$\boxed{\phi_{\text{net}} = \oint \vec{E} \cdot d\vec{A} = \frac{q_{\text{inside}}}{\epsilon_0}}$$

Gauss's law